CLAIMS

What is claimed is:

1. A method for determining state of charge of plural series connected electrical energy storage units, comprising:

applying a non-dissipative load to a selected storage unit in a string of electrical energy storage units, resulting in an energy transfer between the selected storage unit and the string of storage units through the non-dissipative load; and

determining state of charge of the selected unit from voltage and current data of the selected storage unit resulting from the energy transfer.

2. The method of claim 1 wherein the energy is transferred by pulsed currents.

3. The method of claim 1 wherein determining the state of charge of the selected storage unit comprises:

calculating an impedance of the selected storage unit from the voltage and current data obtained during the energy transfer.

4. A method for balancing state of charge among plural series connected electrical energy storage units, comprising:

applying a non-dissipative load to a selected storage unit in a string of electrical energy storage units, resulting in an energy transfer between the selected storage unit and the string of storage units through the non-dissipative load;

determining state of charge of the selected unit from voltage and current data of the selected storage unit resulting from the energy transfer; and

when the state of charge of the selected unit is different than a target state of charge, transferring energy between the selected unit and the string of storage units, such that the state of charge of the selected unit converges toward the target state of charge.

5. The method of claim 4, comprising:

applying an up-converter to the selected storage unit; and

transferring units of energy from the selected storage unit to the string of storage units.

6. The method of claim 4, comprising:

applying a down-converter to the selected storage unit; and

transferring units of energy from the string of storage units to the selected storage unit.

7. The method of claim 4, wherein determining the state of charge of the selected storage unit comprises:

calculating an impedance of the selected storage unit from the voltage and current data obtained during the energy transfer.

8. The method of claim 7, wherein determining the state of charge of the selected storage unit further comprises:

applying the non-dissipative load to the selected storage unit;

determining a first voltage across the selected storage unit;

determining a first current flowing through the selected storage unit;

determining a second voltage from the first current and impedance of the selected storage unit; and

determining the state of charge based on a voltage difference between the first and second voltages.

9. The method of claim 4, wherein the energy is transferred by pulsed current.

10. The method of claim 4, wherein each of the storage units is a storage cell.

11. The method of claim 4, wherein each of the storage units is a battery module.

12. The method of claim 4, wherein one or more of the storage units comprise a battery pack.

13. The method of claim 4, wherein for each storage unit in the string having a number of storage units, comprising:

applying the non-dissipative load to a selected storage unit, resulting in an energy transfer between the selected storage unit and the string of storage units through the non-dissipative load; and

determining an impedance of the selected storage unit from voltage and current data of the selected storage unit obtained during the energy transfer.

14. The method of claim 13, further comprising:

determining a string impedance from the determined impedance of each storage unit;

determining a first string voltage and string current from the string of storage units;

determining a second string voltage from the string current and the string impedance;

determining a string voltage difference between the first string voltage and the second string voltage; and

determining a target state of charge as a ratio of the string voltage difference to the number of storage units.

15. The method of claim 14, further comprising:

selecting a storage unit from the string of storage units having a state of charge that is different from the target state of charge;

transferring energy between the selected storage unit and the string of storage units, such that the state of charge of the selected unit converges toward the target state of charge.

16. The method of claim 15, wherein selecting a storage unit from the string of storage units having a state of charge that is different from the target state of charge, comprises:

comparing each of the states of charge of the individual storage units with the target state of charge; and

selecting a storage unit having a state of charge most different from the target state of charge.

17. The method of claim 15, wherein selecting a storage unit from the string of storage units having a state of charge that is different from the target state of charge, comprises:

selecting a storage unit having a state of charge that is different from the target state of charge from the string of storage units in a sequential order.

18. The method of claim 15, wherein transferring energy between the selected storage unit and the string of storage units, comprises:

comparing the state of charge of the selected storage unit with the target state of charge;

when the state of charge is less than the target state of charge, transferring energy from the string of storage units to charge the selected storage unit; and

when the state of charge is greater than the target state of charge, transferring energy from the selected storage unit to charge the string of storage units.

19. The method of claim 18, comprising:

when the state of charge is less than the target state of charge, transferring energy from the string of storage units to charge the selected storage unit until a charge time expires.

20. The method of claim 18, comprising:

when the state of charge is greater than the target state of charge, transferring energy from the selected storage unit to charge the string of storage units until a discharge time expires.

21. A system for determining state of charge of plural series connected electrical energy storage units, comprising:

a non-dissipative load being applied to a selected storage unit in a string of electrical energy storage units, resulting in an energy transfer between the selected storage unit and the string of storage units; and

a controller determining state of charge of the selected unit from voltage and current data of the selected storage unit resulting from the energy transfer.

22. The system of claim 21, wherein the energy is transferred by pulsed current.

23. The system of claim 21, wherein the controller calculates an impedance of the selected storage unit from the voltage and current data obtained during the energy transfer.

24. A system for balancing state of charge of plural series connected electrical energy storage units, comprising:

a non-dissipative load being applied to a selected storage unit in a string of electrical energy storage units, resulting in an energy transfer between the selected storage unit and the string of storage units;

a controller determining state of charge of the selected unit from voltage and current data of the selected storage unit obtained during the energy transfer; and

when the state of charge of a selected unit is different than a target state of charge, the controller directing the non-dissipative load to transfer energy between the selected storage unit and the string of storage units, such that the state of charge of the selected unit converges toward the target state of charge.

25. The system of claim 24, wherein the non-dissipative load is an up-converter transferring units of energy from the selected storage unit to the string of storage units.

26. The system of claim 24, wherein the non-dissipative load is a down-converter transferring units of energy from the string of storage units to the selected storage unit.

27. The system of claim 24, wherein the controller calculates an impedance of the selected storage unit from the voltage and current data obtained during the energy transfer.

28. The system of claim 27, wherein:

the non-dissipative load is applied to the selected storage unit;

the controller determines a first voltage across the selected storage unit;

the controller determines a first current flowing through the selected storage unit;

the controller determines a second voltage from the first current and impedance of the selected storage unit; and

the controller determines the state of charge based on a voltage difference between the first and second voltages.

29. The system of claim 24, wherein the energy is transferred by pulsed current.

30. The system of claim 24, wherein each of the storage units is a storage cell.

31. The system of claim 24, wherein each of the storage units is a battery module.

32. The system of claim 24, wherein one or more of the storage units comprise a battery pack.

33. The system of claim 24, wherein for each storage unit in the string having a number of storage units:

the non-dissipative load is applied to a selected storage unit, resulting in an energy transfer between the selected storage unit and the string of storage units; and

the controller determines an impedance of the selected storage unit from voltage and current data of the selected storage unit observed from the energy transfer.

34. The system of claim 33, wherein:

the controller determines a string impedance from the determined impedance of each storage unit;

the controller determines a first string voltage and string current from the string of storage units;

the controller determines a second string voltage from the string current and the string impedance;

the controller determines a string voltage difference between the first string voltage and the second string voltage; and

the controller determines a target state of charge as a ratio of the string voltage difference to the number of storage units.

35. The system of claim 34, wherein:

the controller selects a storage unit from the string of storage units having a state of charge that is different from the target state of charge; and

the controller directs the non-dissipative load to transfer energy between the selected storage unit and the string of storage units, such that the state of charge of the selected unit converges toward the target state of charge.

36. The system of claim 35, wherein:

the controller compares each of the states of charge of the individual storage units with the target state of charge; and

the controller selects a storage unit having a state of charge most different from the target state of charge.

37. The system of claim 35, wherein:

the controller selects a storage unit having a state of charge that is different from the target state of charge from the string of storage units in a sequential order.

38. The system of claim 35, wherein:

the controller compares the state of charge of the selected storage unit with the target state of charge;

when the state of charge is less than the target state of charge, the controller directing the non-dissipative load to transfer energy from the string of storage units to charge the selected storage unit; and

when the state of charge is greater than the target state of charge, the controller directing the non-dissipative load to transfer energy from the selected storage unit to charge the string of storage units.

39. The system of claim 38, wherein:

when the state of charge is less than the target state of charge, the controller directing the non-dissipative load to transfer energy from the string of storage units to charge the selected storage unit until a charge time expires.

40. The system of claim 38, wherein:

when the state of charge is greater than the target state of charge, the controller directing the non-dissipative load to transfer energy from the selected storage unit to charge the string of storage units until a discharge time expires.